water resources

The Earth's water resources comprise the total volume of freshwater available for human use and management. Less than 3% of the Earth's total volume of water is fresh, and almost four-fifths of this is essentially unavailable because it is in the form of glacial ice. Of the remaining quantity of liquid freshwater, most is underground, with an average of only 5% present as surface water--lakes and streams--at any time.

Water resources are more meaningfully measured in terms of flow rates, rather than volumes, however. The average precipitation rate is the rate at which water is delivered to the land, but a significant portion of this (two-thirds on a worldwide basis) returns directly to the atmosphere through the process of EVAPOTRANSPIRATION (evaporation from lakes and rivers plus transpiration by plants). Although evapotranspiration represents a loss in terms of water available for direct human use and management, it performs vital functions by supporting the growth of forests, crops, and other vegetation. The difference between precipitation rate and evapotranspiration rate is called the runoff rate or water yield. This runoff eventually enters the surface-water system of rivers and streams (see RIVER AND STREAM) and lakes (see LAKE), either directly or as groundwater seepage.

RUNOFF

The world average runoff rate represents about 39,000 cu km per year [28.1 x 10(12) gal/day]. This flow is the amount theoretically available for direct human use and management, and represents a maximum estimate of world water resources.

The groundwater component of runoff is not a separate water resource from surface water. GROUNDWATER is recharged by percolation of rain and snowmelt and flows into lakes and streams as an integral part of the interconnected system by which runoff drains ultimately to the ocean. The actual amount of water available to supply human needs is substantially less than the total average runoff, streamflow being highly variable over time, so runoff from groundwater represents the more realistic estimate of the manageable water resource available on a continental basis.

The runoff rate within continents is considerably variable. Measured in terms of total runoff divided by the land area concerned, for example, in the United States the average runoff is 230 mm/yr (9 in/yr) but varies from less than 25 mm/yr (1 in/yr) in the nonmountainous regions of the West to 500 mm/yr (20 in/yr) in the East, and more than 1,000 mm/yr (40 in/yr) in the mountains of the West.

As suggested above, the time variability of streamflow is the critical factor in developing a practical estimate of the water resources of a region. This variability is determined by: the climate, particularly the seasonal and year-to-year variations in PRECIPITATION, evapotranspiration, and snowmelt; the degree to which groundwater seepage contributes to streamflow; and the degree to which lakes, swamps, and reservoirs store streamflow and reduce its variability. Most water uses require that a firm flow rate be available at least 90% of the time. This firm flow, generally the most realistic definition of available water resources, often represents 10% or less of the average flow.

USES AND NEEDS

Consideration of WATER QUALITY as well as of flow variability is also important in evaluating water resources, because water cannot be applied to a given use unless its quality is suitable for that use.

Use of water can be classified in two major ways: instream use versus withdrawal, and consumptive versus nonconsumptive use. Instream uses include navigation, generation of hydroelectric power, maintenance of water quality, provision for fish and wildlife habitat, and fulfillment of aesthetic goals. (It should also be recognized that freshwater discharging into the near-shore ocean environment may play economically and ecologically important roles with respect to salinity balances and near-shore currents). Withdrawal uses involve removal of water from streams or groundwater. Water that is either evaporated, transpired, incorporated into products, or discharged into a saltwater body, where it is not available for reuse, is said to be consumed.

The demand for the water resource in any stretch of river is the sum of the amount required for instream purposes (such as maintenance of water quality), plus the amount required for withdrawal. That which is withdrawn but not consumed is available for reuse downstream, usually after treatment.

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Total worldwide water withdrawal is approximately 2,400 cu km per year [1.7 x 10(12) gal/day] and is allocated as follows: 2% to rural domestic uses, 8% to urban domestic uses, 8% to industrial uses, and the remaining 82% to agricultural IRRIGATION. Projections for the middle of the 21st century are an almost tenfold growth in world water withdrawals, to about 20,000 cu km per year [14.5 x 10(12) gal/day]. This figure is well beyond the net firm flow of the world's rivers; water may therefore become a scarce resource limiting population growth during the next century. The above figures do not include at least 10,000 cu km per year [7.2 x 10(12) gal/day] estimated instream requirements for maintaining water quality.

In the United States, total withdrawals of freshwater amount to about 480 cu km/yr [0.35 x 10(12) gal/day], of which 74% come from surface water and 26% from groundwater. This water is allocated as follows: 58% to industry, 34% to irrigation, 7% to urban water supplies, and 1% to rural water supplies. Of the water withdrawn, only 23% is used consumptively. Irrigation is by far the heaviest consumer of water, accounting for 83%, whereas urban supplies account for 7%, industry for 6%, and rural supplies for 4%.

On a worldwide basis, the United States, the Soviet Union, India, and China are by far the largest users of water. Together the four nations withdraw about 45% of the total amount worldwide. As compared to the United States, the Soviet Union uses about 51% of its withdrawn water for irrigation, about 45% for industry and electricity production, and about 4% for domestic purposes. India uses almost 96% of its withdrawn water for irrigation, only about 3% for industry and electricity production, and 1% for domestic purposes. China uses about 93% of its withdrawn water for irrigation, about 5% for industry and electricity production, and 2% for domestic purposes.

Of these four leading nations, the United States is the only one that already had ore land under irrigation than it requires. In fact, some areas have already stopped crop irrigation because of depletion of groundwater supplies. All four nations face increasing problems of pollution of their water resources, and China, India, and the Soviet Union also face special problems of distribution of those resources.

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